



VERIFICATION OF TRANSLATION

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[Title of the Invention] Fuel Evaporator

[Claims]

[Claim 1]

A fuel evaporator composed of an evaporation chamber which evaporates a raw liquid fuel by a high temperature thermal medium to provide a raw fuel gas,

said evaporation chamber comprising a plurality of evaporation chambers serially connected to each other in a ventilation manner, and

at least one raw liquid fuel injector for injecting said raw liquid fuel being provided on each of said plurality of evaporation chambers.

[Claim 2]

The fuel evaporator according to Claim 1, wherein a plurality of the raw liquid injector are provided on any one of said plurality of evaporation chambers.

[Claim 3]

The fuel evaporator according to Claim 1 or 2, which further comprise a controller for said raw liquid fuel injector, which, upon receiving a signal for the requirement of said raw fuel gas, selects the raw liquid fuel injector or injectors from which the raw liquid fuel is injected.

[Claim 4]

The fuel evaporator according to any one of Claims 1 to 3, which has a heat receiving portion for receiving the heat

from the heat source, which generates said high temperature thermal medium, provided near the bottom of one of said evaporation chamber, and has a slope downward to said heat receiving portion provided on the bottom of another evaporation chamber or chambers.

[Claim 5]

The fuel evaporator according to Claim 4, wherein one of said evaporation chambers is formed so that the thermal conductive area thereof is larger than that or those of another evaporation chamber or chambers, and said heat receiving portion is provided on the bottom of said evaporation chamber having a larger thermal conductive area.

[Detailed Description of the Invention]

[0001]

[Technical Field]

The present invention relates to a fuel evaporator which can be suitably utilized in a fuel cell system in which a raw fuel gas produced by evaporating a raw liquid fuel is reformed in a reformer, and then supplied to a fuel cell to generate electricity.

[0002]

[Prior Art]

A fuel cell system is a power generation system mainly comprising a fuel cell, which generates power by supplying hydrogen as a fuel gas to a hydrogen pole and by supplying an oxidant gas containing oxygen to an oxygen pole. The fuel cell

system, which directly converts a chemical energy into an electric energy, has increasingly been attractive due to its high generation efficiency and discharging little harmful substance.

[0003]

As a fuel evaporator, which can be used in the conventional fuel cell system, our Japanese Patent Application No. 11-125366 (not disclosed) can be mentioned. As shown in FIG. 11, this fuel evaporator 100 is composed of a body 110 of the fuel evaporator and a superheating portion 150 residing at the downstream of the body 110 of the fuel evaporator, and a raw fuel injection apparatus 140 provided on the upper portion of the body 10. Into this fuel evaporator 100, is supplied a combustion gas HG (high temperature thermal medium) obtained by catalytically combusting a hydrogen-containing off gas, which is generated in the fuel cell (not shown), in a catalytic combustor (not shown) as a heat source. The combustion gas HG enters from an inlet 112_{in}, and is passed through the inside of a plurality of U-shaped tubes 112 for thermal medium (referred to as thermal medium tubes) provided in a evaporation chamber 111 within the body 110 of the fuel evaporator to reach an outlet 112_{out}. Subsequently, the combustion gas HG is passed through a combustion gas passage 113 provided on the lower portion of the body 110 of the fuel evaporator, and introduced into the superheating portion 150 provided downstream of the body 110 of the fuel evaporator. The raw liquid fuel FL composed

of a mixture of methanol with water is injected from the raw liquid fuel injector 140 in the state of mist, is heated on the thermal medium tubes 112 and is evaporated to be the raw fuel gas FG. The raw fuel gas FG is passed through the interior of evaporation tube 151 provided within the superheating portion 150 to be superheated and then introduced into a reformer (not shown) residing at the downstream of the superheating portion 150.

[0004]

In this fuel evaporator 100, the lower surface 111b of the evaporation chamber 111 in the body 110 of the fuel evaporator also serves as the upper surface 113t of the combustion gas passage 113. Consequently, since heat is also supplied from the lower surface 111b of the evaporation chamber 111, the generation of the liquid residence is prevented and, even if the liquid residence occurs, the liquid can be quickly evaporated. Accordingly, the fuel evaporator 110 is of good response. Also, the warming up of the fuel evaporator 110 can be conducted in a quick manner.

However, the combustion gas HG, which is a heat source of the conventional fuel evaporator 100 is changed depending upon the operation conditions of the fuel cell and, thus, it is required that a required amount of the raw liquid fuel FL should be evaporated using heat of combusting hydrogen and then is supplied to the reactor. However, there is a problem that the situations of the evaporation in the evaporation chamber 111

(e.g., generation of liquid residence) and the temperature of the raw fuel gas FG are changed by various factors such as the change in the heating value supplied (change in the operation conditions), heat mass of the fuel evaporator itself, and change in atmospheric temperature.

[0005]

In the case where the fuel cell system is carried on an fuel cell/electric automobile, it is required for the fuel evaporator that the raw liquid fuel is quickly evaporated at the time of starting the system or of sharply changing the load, i.e., the raw fuel gas is obtained with much better response. Furthermore, it is desired for driving the reformer under good conditions that the raw fuel gas is supplied at an appropriate temperature without unevenness of the temperature. In addition, if the raw fuel gas having an appropriate temperature range is obtained at the time of heavy load state, the conventional fuel evaporator has a problem that the temperature of the raw fuel gas under middle or low load conditions becomes unduly high.

[0006]

[Problem to be Solved by the Invention]

An object of the present invention is, therefore, to provide a fuel evaporator, which can secure sufficient response to a sharp change in the load, which can supply a raw fuel gas at an appropriate temperature into the later reformer, and which can satisfy high requirements of the fuel cell system for carrying a fuel cell/electric automobile.

[0007]

[Means for Solving Problems]

According to Claim 1, which attains the object, is a fuel evaporator composed of an evaporation chamber which evaporates a raw liquid fuel by a high temperature thermal medium to provide a raw fuel gas, said evaporation chamber comprising a plurality of evaporation chambers serially connected to each other in a ventilation manner, and at least one raw liquid fuel injector for injecting said raw liquid fuel being provided on each of said plurality of evaporation chambers.

[0008]

When the evaporation chamber is divided into several evaporation chambers and when the raw liquid fuel is individually injected to each of the evaporation chambers according to the evaporation performance of respective evaporation chamber, any dead space during the course of the injection and uneven injection of the raw liquid fuel into the thermal medium tubes which are heat-conductive tubes and, thus the heat efficiency per unit volume of the evaporation chamber is increased.

[0009]

The fuel evaporator according to Claim 2, a plurality of the raw liquid injector are provided on any one of said plurality of evaporation chambers.

[0010]

In a large-sized evaporation chambers having a large

thermal capacity and a large evaporation performance, a large amount of raw fuel gas can be rapidly supplied by simultaneously spraying raw fuel in a large amount from a plurality of the raw liquid injector.

[0011]

The invention of Claim 3 is the fuel evaporator according to Claim 1 or 2, which further comprise a controller for said raw liquid fuel injector, which, upon receiving a signal for the requirement of said raw fuel gas, selects the raw liquid fuel injector or injectors from which the raw liquid fuel is injected.

[0012]

According to this configuration, depending up the raw fuel gas required, it can be judged the raw fuel gas should be injected to which evaporation chamber and to how many evaporation chamber. Also, in comparison with the evaporation chamber composed of only one evaporation chamber, when the evaporation chamber having the same capacity as in that of the evaporation chamber composed of only one evaporation chamber is divided into several chambers, and raw liquid fuel is separately injected according to the evaporation performance of each evaporation chamber, the uneven injection to dead space during the injection or tubes for thermal medium which is thermal transmitting tubes can be decreased and, thus, the heat efficiency per unit volume of the evaporation chamber is increased. As a result, the evaporation is instantly brought

about. This makes it possible to quickly supply the required amount of the raw fuel gas at the time of the requirement.

[0013]

The invention of Claim 4 concerns a fuel evaporator according to any one of Claims 1 to 3, which has a heat receiving portion for receiving the heat from the heat source, which generates said high temperature thermal medium, provided near the bottom of one of said evaporation chamber, and has a slope downward to said heat receiving portion provided on the bottom of another evaporation chamber or chambers.

[0014]

By passing the combustion gas through the interior of the fuel evaporator, the evaporation of the raw liquid fuel is further accelerated, which allows for the fuel evaporator excelling in good response. This also allows for rapid warming up.

[0015]

The invention of Claim 5 concerns fuel evaporator according to Claim 4, wherein one of said evaporation chambers is formed so that the thermal conductive area thereof is larger than that or those of another evaporation chamber or chambers, and said heat receiving portion is provided on the bottom of said evaporation chamber having a larger thermal conductive area.

[0016]

In the evaporation chamber having a large heat conductive

area (larger number of heating tubes), and having heat receiving portion provided on the bottom of the evaporation chamber, much more heat can be provided and, thus, the raw fuel gas can be obtained quickly, and can be supplied in good response.

[0017]

[Embodiments of Invention]

The fuel evaporator of the first embodiment will now be described by referring to FIG. 1 to FIG. 11.

Fig. 1 shows the configuration of a fuel cell system, in which a fuel evaporator according to the first embodiment of the present invention is used. Fig. 2 is a partial cutaway plane view of the fuel evaporator according to the fourth embodiment of the present invention. Fig. 3 is a cross-sectional view taken along the line A-A of Fig. 2. Fig. 4 is a cross-sectional view taken along the line B-B of Fig. 2. Fig. 5 is a cross-sectional view taken along the line C-C of Fig. 2. Fig. 6 is a block diagram showing the control system of the fuel evaporator according to the fourth embodiment of the present invention.

Fig. 7 is a drawing showing the relation between the position of injection of the raw liquid fuel in an evaporation chamber and the temperature of the raw fuel gas at the outlet of the evaporation chamber. Fig. 8(a) is a drawing explaining an aimed temperature range and a tolerance temperature range of the raw fuel gas, and Fig. 8(b) shows a basic injection

pattern at a stationary state. Fig. 9 is a flowchart showing the control of the fuel evaporator according to the present invention at a stationary state.

Fig. 10 is a flowchart showing the control of the fuel evaporator according to the present invention at an accelerated state. Fig. 11 shows the relation between the temperature of the raw fuel gas generated during the evaporation of the raw liquid fuel and the operation power.

[0018]

Referring to Figs. 1 and 2, the whole of the fuel cell system FCS will be described.

The fuel cell system FCS is composed mainly of a fuel evaporator 1, a reformer 2, a CO remover 3, an air compressor 4, a fuel cell 5, a gas/liquid separator 6, a combustion burner 7, and a tank T for a raw liquid fuel (a tank for storing a water/methanol mixed liquid).

As shown in Fig. 3, the tubes 12A in the first evaporation chamber are placed so that the distances between the respective thermal medium tubes 12A become wider toward the upper direction and they become narrower toward the lower direction (i.e., the thermal medium tubes become sparser as they are near from the injector 41A, and they become denser as they are far from the injector 41A), in order to widespread the raw liquid fuel FL injected from the injector 41A among every portions of the evaporation chamber 12A including the portion far from the injector 41A. Also, by such a configuration, the generation

of big film boiling such as the film boiling spread between the thermal medium tubes 12A can be reduced (i.e., the distances between the thermal medium tubes 12A at the portion near the injector 41A are widened to prevent greatly grow in the portions where the film boiling occurs), to thereby secure the passages of the raw liquid fuel FL and the raw fuel gas FG. By placing the tubes 12A at the lower portion of the first evaporation chamber 11A in a dense manner, and by strongly heating the lower portion of the first evaporation chamber 11A, the liquid residence on the lower portion of the first evaporator chamber 11A can also be prevented (the generation of the liquid residence on the lower portion of the first evaporator 11A is also prevented by increasing the heat mass at the lower portion of the first evaporation chamber 11A). With regard to the placements and the functions of the thermal medium tubes 12B and 12C in the second and third evaporation chambers 11B and 11C, they are substantially the same as those of the tubes 12A in the first evaporation chamber 11A.

[0019]

Functions of the fuel cell system FCS composed as described above will be described.

The raw fuel gas injection apparatus 40 is an injection apparatus having a single fluid nozzle and injects the raw fuel gas FG into the evaporation chamber 11. The raw fuel gas injection apparatus 40 comprises injectors 41 for injecting the raw fuel gas FL and a tube 42 for supplying the raw liquid fuel

FL, and is provided on the upper surface 11t of the evaporation chamber. The injectors 41 are provided on the first evaporation chamber 11A, the second evaporation chamber 11B, and the third evaporation chamber 11C, respectively. Specifically, three injectors 41A₁, 41A₂, and 41A₃ are provided on the first evaporation chamber 11A, one injector 41B is provided on the second evaporation chamber 11B, and one injector 41C is provided on the third evaporation chamber 11C. In order to effectively utilize the thermal value possessed by the high temperature combustion gas HG, the raw liquid fuel FL is mainly injected to the direction along the plurality of the thermal medium tubes 12A, 12B, and 12C provided within the evaporation chamber 11 (in each of the evaporation chambers, the direction toward the supporting plate 12Aa or 12Ba of the thermal medium tubes 12A, 12B, or 12C).

[0020]

The raw fuel gas FG generated at the body 10 of the evaporator and introduced into the reformer 2 is subjected to be reacted on a solid catalyst (e.g., Cu-Zn catalyst) to produce a hydrogen-enriched raw fuel gas, from which carbon monoxide is removed by the CO remover 3, and then introduced into the fuel cell 5. The exhaust gas OG at the hydrogen pole of the fuel cell 5 from which moisture is separated and removed by the gas-liquid separator 6 is combusted again at the catalytic combustor 20, which can be used as the heat source for the body 10.

[0021]

Characteristic configurations of the fuel evaporator 1 of the embodiment will now be described by referring to FIG. 1 to 11.

As shown in Figs. 3 to 5, the fuel evaporator according to the fourth embodiment mainly comprises:

a body 10 of the fuel evaporator composed of a evaporation chamber 11 having evaporation chambers 11A, 11B, and 11C, each having tubes 12A, 12B, or 12C for thermal medium and a tube supporter 12Aa, 12Ba, or 12Ca for holding the respective thermal medium tube provided thereon to serially connect these evaporation chamber with each other in a ventilation manner, and gas passages P1 to P11 surrounding around of the evaporation chamber 11;

a raw liquid fuel injection apparatus 40 formed from a tube 42 for supplying the raw liquid fuel FL and injectors 41A, 41B, and 41C, which are means for injecting the raw liquid fuel, each provided on the lower portion of the tube 42 for supplying the raw liquid fuel;

a catalytic combustor 40, which is a means for providing a heat source provided on the lower portion of the evaporation chamber 11A and which generates a combustion gas HG serving as the high temperature thermal medium; and

a controller 100 for the injection of the raw liquid fuel, which receives a signal required for the raw fuel gas to select any of injector or injectors 41A, 41B, and 41C, so that the a

predetermined amount of the raw liquid fuel FL is injected from the selected injector(s).

[0022]

The body 10 of the fuel evaporator is composed of the evaporation chamber 11 and gas passages P1 to P11 surrounding around of the evaporation chamber 11.

As shown in Fig. 3, the evaporation chamber 11 is composed of three evaporation chambers, i.e., a first evaporation chamber 11A having the highest evaporation performance (having the largest number of the thermal medium tubes 12A), a second evaporation chamber 11B having the next highest evaporation performance (having the next largest number of the thermal medium tubes 12B), and a third evaporation chamber 11C (having the smallest number of the thermal medium tubes 12C), and is a boxy chamber having these three chambers serially connected with each other in a ventilation manner.

The order where each of the chambers is connected is not specifically restricted. For example, the first evaporation chamber 11A may reside between the second evaporation chamber 11B and the third evaporation chamber 11C.

Within the evaporation chamber 11, a predetermined amount of the raw liquid fuel FL is injected onto the external surfaces of the thermal medium tubes from selected injector(s) whose injection amount of the raw liquid fuel FL is determined by the controller 100 depending upon the evaporation performance. With regard to the direction of injecting the raw liquid fuel

FL by each of the injectors 41A, 41B, and 41C, the raw liquid fuel FL is injected toward the inlet side of the thermal medium tubes 12A, 12B, or 12C each provided on the evaporation chamber 11A, 11B, or 11C (the entrance side of the combustion gas HG).

As described above, in comparison with the evaporation chamber composed of only one evaporation chamber, when the evaporation chamber having the same capacity as in that of the evaporation chamber composed of only one evaporation chamber is divided into several chambers, and raw liquid fuel FL is separately injected according to the evaporation performance of each evaporation chamber, the uneven injection to dead space during the injection or tubes for thermal medium which is thermal transmitting tubes can be decreased and, thus, the heat efficiency per unit volume of the evaporation chamber is increased. As a result, the evaporation is instantly brought about. This makes it possible to quickly supply the required amount of the raw fuel gas at the time of the requirement.

These functions are the same as those of the first embodiment.

[0023]

The raw fuel gas injection apparatus 40 is provided on the upper portion of the fuel evaporator 11, and as shown in Fig. 3, it is composed of the tube 42 for supplying the raw liquid fuel which is a manifold tube for supplying the raw liquid fuel FL to the injectors 41A, 41B, and 41C, and injectors 41A, 41B, and 41C each of which is provided on the upper portion of the

evaporator 11A, 11B, or 11C and injects a controlled amount of the raw liquid fuel FL.

The injectors 41A, 41B, and 41C each is a single fluid nozzle, and the flow amount is controlled by means of a nozzle backpressure. As shown in Figs. 18 and 19, three injectors (41A₁, 41A₂, and 41A₃) are provided on the upper portions of the first evaporation chamber 11A having the highest evaporation performance (having the largest number of the thermal medium tubes 12A), and one injector (41B or 41C) is provided on each of the second evaporation chamber 11B having the next highest evaporation performance (having the next largest number of the thermal medium tubes 12B), and the third evaporation chamber 11C (having the smallest number of the thermal medium tubes 12C).

As described above, by injecting a large amount of the raw liquid fuel from a plurality of the injectors over a wide area of the evaporation chamber having significantly high evaporation performance at the same time, a large amount of raw fuel gas can be quickly supplied (at the time of acceleration). Consequently, the fuel evaporator according to this embodiment is of sufficiently responsibility to a sharp and large load requirement.

[0024]

The thermal medium tubes 12A, 12B, and 12C are provided within the evaporation chambers 11A, 11B, and 11C, allow for the flow of a combustion gas HG, which is a high temperature

thermal medium, and evaporates the raw liquid fuel FL in contact with the outer surface of the thermal medium tubes.

Thermal medium tubes 12A, 12B, and 12C each has a U-shape in which at least part of the upper piping is slanted downwardly to the tube supporter 12Aa, 12Ba, or 12Ca. Also, the tube supporters 12Aa, 12Ba, and 12Ca are provided, which support both ends of the thermal medium tubes 12A, 12B, and 12C. By such a formation, the droplets of the raw liquid fuel FL adhered on the upper portions of the tube can be evaporated in a suitable manner by transferring the droplets toward the tube supporters 12Aa, 12Ba, and 12Ca having been heated due to thermal conduction from the catalytic combustor 20. Also, providing the tube supporters 12Aa, 12Ba, and 12Ca as wall portions prevents, the mixing of the combustion gas HG with the raw fuel gas FG within the evaporation chambers 11A, 11B, and 11C.

The piping of the thermal medium tubes 12A, 12B and 12C within the respective evaporation chambers 11A, 11B, and 11C is arranged so that the upper portion is sparser and the lower portion is denser. Such a formation makes it difficult to bring about the liquid residence due to increased heat mass on the bottom.

With regard to the pipe diameters of respective thermal medium tubes 12A, 12B, and 12C, all of the thermal medium tubes used have the same diameter.

[0025]

As shown in Fig. 3, a diaphragm is provided between the

first evaporation chamber 11A and the second evaporation chamber 11B. An upper inlet having a height same as the thickness of the thermal medium tubes on the upper portion of the diaphragm 11P, and a lower open is provided between a bottom plate 11b serving as a heat receiver and the diaphragm 11p. Part or whole of the conjunction portion of the lower open is opened. The diaphragm 11p has a cross-sectional shape so that the portion upper than the upper open is in a rectangle form and the portion lower than the upper open is in a reversed Y form. It is noted that similar diaphragm 11P is provided between the second evaporation chamber 11B and the third evaporation chamber 11C.

[0026]

In addition to three injectors $41A_1$, $41A_2$, and $41A_3$ for injecting the raw liquid fuel FL, the upper portion of the first evaporation chamber 11A having the highest evaporation performance due to the possession of much more thermal medium tubes 12A and its bottom residing near the catalytic combustor 20, an air inlet 15 for supply of the air, which supplies the air required for the reformation caused in the later reformer 2, mixed with the raw liquid fuel FL is provided as shown in Fig. 2. Preference is to the provision of the evaporation chamber having the highest heat value and highest evaporation performance.

In such a formation, since the raw fuel gas FG collides with the respective thermal medium tubes 12A, 12B, and 12C

provided within the respective evaporation chamber 11A, 11B, and 11C, and since the diaphragm 11P is perfectly mixed with the air, the raw fuel gas FL having a uniform composition can be introduced into the latter reactor, i.e., the reformer 2.

[0027]

As shown in Figs. 3 and 4, the bottom plate 11b severing as the heat receiver is provided on the first evaporation chamber 11A near or in contact with a ceiling 20t of the catalytic combustor 20, which is the heat source. The bottom plate 11b near or in contact with the ceiling 20t makes it possible to securely transmit the heat from the catalytic combustor 20 to the evaporation chamber 11A. Also, by increasing the amount of the combustion gas in the catalytic combustor 20, the heat value required in the evaporation chamber 11A can always be supplied.

It is noted that the catalytic combustor 20 may be provided on any other evaporation chamber.

As described above, when one evaporation chamber is configured to have a thermal conductive area (possession of much more thermal medium tubes) wider than other evaporation chamber(s) and to provide the bottom plate severing as the heat receiver, the raw fuel gas can instantly provide from such a evaporation chamber having the wider thermal conductive area by imparting a larger heat value.

[0028]

The bottom plate 11b of the second evaporation chamber 11b

and the third evaporation chamber 11C is made of one plate communicated with the bottom plate 11b, and as shown in Fig. 19, a slope is formed toward the first evaporation chamber 1A.

By providing the catalytic combustor 20, which is the heat source, near or in contact with any of the bottom of the evaporation chambers, providing the bottom plate, which serves as the heat receiver, on the evaporation chamber near or in contact with the catalytic combustor 20, and providing the slope downward to the heat receiver side of the evaporation chamber, the remaining raw liquid fuel FL, which is not evaporated in the evaporation chamber, moves along the slope to be collected on the heat receiver rapidly heated, at which the remaining raw liquid fuel FL is evaporated. Consequently, the predetermined amount of the raw fuel gas can be obtained with good response.

[0029]

As shown in Figs. 3 and 4, the catalytic combustor 20 has a rectangular cross-sectional shape, and is provided near or in contact with the bottom of the evaporation chamber 11A.

The catalytic combustor 20 is composed of an inlet 21 which introduce the off gas OG of the hydrogen pole of the fuel cell 5, which is a substance to be combusted, a catalytic layer 22 which catalyzes the off gas OG due to the combustion reaction, and an outlet 23 having a diaphragm 24 configured so that the flow direction of the combustion gas HG, which is the high temperature thermal medium can be turned 180°. The diaphragm

24 also plays a role in preventing the combustion gas at the outlet side of the evaporation chamber 11A from being mixed with the combustion gas HG at the outlet 24 of the catalytic combustor 20.

[0030]

Around the respective evaporation chamber 11A, 11B, and 11C, combustion gas passages P1 to P11 is formed, which allows for the combustion gas exiting the respective evaporation chamber 11A, 11B, and 11C for flowing. The formation of the combustion gas passages P1 to P11 can preserve the temperature within the evaporation chamber and heat the interior of the evaporation chamber and, thus, the raw liquid fuel FL can more suitably evaporated.

[0031]

Subsequently, the functions of the fuel evaporator 1 according to the fourth aspect will now be described by referring to Figs. 2 to 5.

As shown in Fig. 4, the off gas OG from the hydrogen pole of the fuel cell 5, which is a gas to be combusted, is passed through the inlet 21 of the fuel evaporator, and flows toward the catalytic layer 22 of the catalytic combustor 20 as is at which the combustion reaction of the off gas is brought about to produce the combustion gas HG, after which the resulting combustion gas HG is discharged to the combustion gas passage P1, which is the base end. The produced combustion gas having a high temperature flows within the U-shaped thermal medium

tubes 12A within the evaporation chamber 11A from the downside to the upside. During the passage through the U-shaped thermal medium tubes, the combustion gas HG evaporates the raw liquid fuel, which is injected from the injector(s) 41A to the outer surface of the thermal medium tubes 12A, to form the raw fuel gas FG.

[0032]

Subsequently, the combustion gas HG, after evaporating the raw liquid fuel FL, is discharged from the outlet 12A_{out} of the thermal medium tube 12A to the combustion gas passage P3, then as shown in Fig. 18, passed through the combustion gas passage P3 (at the center front side of the evaporation chamber 11A), the combustion gas passage P4 (left front side of the evaporation chamber 11A), the combustion gas passage P5 (rear side of the evaporation chamber 11A), and enters into the combustion gas passage P6, these passages being provided so as to surround the evaporation chamber 11A. As shown in Fig. 21, the combustion gas HG having a high temperature is branched into two ways from the combustion gas passage P6, flows within the tubes 12B and 12C, respectively (combustion gas passages P7 and P8) from the downside to the upside, and is passed through the combustion gas passage P9 residing at rear surface (side) viewing from the front side, through the combustion gas passages P10 provided on the bottoms of the evaporation chambers 11B and 11C and through the combustion gas passage P11 making up the terminals of the sides of the evaporation chambers

11B and 11C, and then discharged out. The functions described herein are those in the case where the injection of the standard injection pattern by the injectors 41A within the evaporation chamber 11A by means of the controller 100 for the raw liquid fuel injection, which will be described later on.

[0033]

On the other hand, as shown in Fig. 19, the raw fuel gas FL evaporated at the first evaporation chamber 11A is passed through the open of the diaphragm 11P, serially through the second evaporation chamber 11B and the third evaporation chamber 11C and then introduced into the reformer 2, which is the later reactor.

[0034]

The controller 100 for the raw liquid fuel injection, which controls the injection amount of the raw liquid fuel FL and the injection position(s) of the injectors 41A, 42B, and 42C, will now be described. In the following description, the controller 100 for the raw liquid fuel injection in the case of carrying the fuel cell system FCS on a vehicle will be assumed.

The term "idling (idle)" to be used herein means the situation where a small amount of the raw fuel gas is generated for maintaining the operation of accessories (e.g., compressor, heater, air conditioner, etc.) even if any amount of the raw fuel gas FG is required by the fuel cell 5.

Also, the term "low load" used herein means a certain

pushing of the accelerator to lowly open the throttle, in which case the required amount of the raw fuel gas is higher than the case of idling.

The term wide opening the throttle (WOT) used herein is in the state where the opening degree of the throttle is the maximum, in which case the required amount of the raw fuel gas is the highest.

[0035]

The positions of the thermo sensors equipped with the fuel evaporator 1 will be described.

As shown in Figs. 3 to 5, three thermo sensors for detecting the temperature of the combustion gas HG are equipped, and three thermo sensors for detecting the temperature of the raw fuel gas are equipped.

Tg_{in} : The temperature of the combustion gas at the outlet of the catalytic combustor (the gas temperature at the inlet of the first evaporator 11A).

wherein the symbols of the thermo sensors detects the following temperatures:

Tg_1 : The temperature of the combustion gas at the outlet of the first evaporation chamber 11A.

Tg_2 : The temperature of the combustion gas at the outlets of the second evaporation chamber 11B and the third evaporation chamber 11C.

Tv_1 : The temperature of the raw fuel gas at the outlet of the first evaporation chamber 11A.

TV₂: The temperature of the raw fuel gas at the outlet of the second evaporation chamber 11B.

Tv₃: The temperature of the raw fuel gas at the outlet of the third evaporation chamber 11C.

[0036]

The controller 30 for the raw liquid fuel injector is a controller which controls the selection of the injector or injectors to be injected and the respective injection amounts based on the detected temperature data, signals for the operation conditions of the stack required from the body of the fuel cell, and the signal of the opening degree of the throttle.

Similar to the first embodiment, in the case of the fourth embodiment, the positions of the injectors, which inject the raw liquid fuel, are switched as shown in Fig. 7. By injecting the raw liquid fuel from the inner part of the evaporation chamber, the temperature of the raw fuel gas at the outlet of the evaporation chamber can be heightened. On the other hand, by injecting the raw liquid fuel from the nearest portion of the outlet of the evaporation chamber, the temperature of the raw fuel gas at the outlet of the evaporation chamber can be lowered.

Utilizing the test results of the temperature of the raw fuel gas depending upon the positions, the invention makes a temperature control resembling the first embodiment.

[0037]

Specifically, similar to the case of the first embodiment,

the basic injection pattern uses the injector 41A₂ in the case where the fuel cell 5 is idling. In the case of the low loading where the required output is higher, the raw liquid fuel is injected from the two injectors 41A₂ and 41A₃. Also, in the case where the required amount is further increased, the combination of the two injectors 41A₂ and 41A₃ is switched to the combination of the two injectors 41A₁ and 41A_w, which can inject larger amount of the raw liquid fuel. In the case where the maximum output is required as in the case of wide opening the throttle (WOT), the raw liquid fuel is injected from the three injectors 41A₁ and 41A₃, and 41A₃. On the other hand, the injectors 41B and 41 are always turned off. By such a configuration the later evaporation chambers 11B and 11C are always in the empty burned and, thus, the temperature of the raw fuel gas FG can be suitably controlled by switching the injectors.

[0038]

As described above, when the controller 100 for injecting the raw liquid fuel where the signal required from the is received, and any of the injector or injectors are selected for injecting the raw liquid fuel, and the raw liquid fuel is injected from the selected injectors is provided, it is possible to judge which and how many evaporation chambers are used for injecting the raw liquid fuel. Also, when the raw liquid fuel is injected to severally divided evaporation chamber rather than one chamber, it is possible to make a dead

space during the course of the injection and reduce any uneven injection to the thermal medium tubes, increasing the heat efficiency per unit volume. As a result, the raw liquid fuel can be instantly evaporated, which makes it possible to quickly supply the required amount of the raw fuel gas. Accordingly, the fuel evaporation of this embodiment can deal with the sharp requirement of the load.

[0039]

By referring to Fig. 9, the control flow of the controller 30 for the raw liquid fuel injection will be described in the case where the temperature is controlled by selecting the positions of the injectors 41A (41A₁, 41A₂, and 41A₃) within the first evaporation chamber 11A, and the injectors 41B and 41C.

1. The controller judges whether or not the fuel evaporator is warming up (S1). If the fuel evaporator is warming up, warming up is carried out through a warming up subroutine (S117) to maintain the warming up.

2. If the fuel evaporator is not warming up, the controller confirms whether or not there is an increase in the opening degree of the throttle ($\Delta\theta_{th}$) (S2).

3. If the increase in the opening degree of the throttle ($\Delta\theta_{th}$) exists, the acceleration is carried out by acceleration subroutine (S118) to maintain the acceleration state.

In the case of the stationary operation where no increase in opening degree of the throttle ($\Delta\theta_{th}$) exists, the basic injection pattern shown in Fig. 8(b) is read, i.e., the

injectors 41 are selected. A map showing the relation between the injection times, T_i , of the injector and the injection amount of the raw liquid fuel is read (S4). From various correction terms (correction terms such as battery voltage), an actually required injection time, T_i , is calculated (S5). The raw liquid fuel FL is intermittently injected from the selected injectors 41A in a pulse-controlled manner (S6).

4. The controller compares the temperature T_{v2} at the outlet of the third evaporation chamber after the injection with the threshold temperature $T_{v_{high}}$ at the higher side (S7).

5. If the temperature T_{v2} at the outlet of the third evaporation chamber after the injection exceeds the threshold temperature $T_{v_{high}}$ at the higher side, the controller operates the following procedures:

(a) The temperature incline, ΔT_v , at the side of the raw fuel gas FG is calculated from the detected raw fuel gas temperatures T_{v1} , T_{v2} , and T_{v3} (S8).

(b) The temperature incline, ΔT_v , at the side of the combustion gas HG is calculated from the detected raw fuel gas temperatures $T_{g_{in}}$, T_{g1} , and T_{g2} (S9).

(c) A table for ΔT_v -injection pattern is read (S10).

(d) On the basis of the ΔT_v -injection pattern, the injection positions of the injectors 41A are switched (S11).

As a specific example, the table for the ΔT_v -injection pattern is provided so that in the case where the raw liquid fuel FL is injected from 41A₁, 41A₂, and 41A₃, when T_{v2} is larger

than $T_{v_{high}}$ ($v_2 > T_{v_{high}}$), the injection position is switched from 41A₁ to 41C. By this series treatment, the temperature T_{v_2} can be decreased to fall within the aimed temperature range.

Thereafter, the step is returned to S1.

6. If the temperature T_{v_2} at the outlet of the third evaporation chamber 11C after the injection is lower than the threshold temperature $T_{v_{high}}$ at the higher side, the temperature T_{v_2} is judged to be the threshold temperature $T_{v_{low}}$ at the lower side (S12). If the temperature T_{v_2} of the raw fuel gas is lower than the threshold temperature $T_{v_{low}}$ at the lower side, Step is returned to S1. If the temperature T_{v_2} of the raw fuel gas exceeds the threshold temperature $T_{v_{low}}$ at the lower side, the controller operates the following procedures:

(e) The temperature incline, ΔT_v , at the side of the raw fuel gas FG is calculated from the detected raw fuel gas temperatures T_{v_1} , T_{v_2} , and T_{v_3} (S13).

(f) The temperature incline, ΔT_v , at the side of the combustion gas HG is calculated from the detected raw fuel gas temperatures $T_{g_{in}}$, T_{g_1} , and T_{g_2} (S14).

(g) A table for ΔT_v -injection pattern is read (S15).

(h) On the basis of the ΔT_v -injection pattern, the injection positions of the injectors 41A are switched (S16).

As a specific example, the table for the ΔT_v -injection pattern is provided so that in the case where the raw liquid fuel FL is injected from 41A₂, when T_{v_2} is lower than $T_{v_{low}}$ ($v_2 < T_{v_{low}}$), the injection position is switched from 41A₂ to 41A₁.

By this series treatment, the temperature Tv_2 can be increased to fall within the aimed temperature range.

Thereafter, the step is returned to S1.

As described above, in order that the temperature at the outlet of the third evaporation chamber 11C at the time of injecting the raw liquid fuel FL by means of the injectors fall within the aimed temperature range based upon the basic injection pattern, the temperature incline, ΔTv , of the detected raw fuel gas temperatures Tv_1 , Tv_2 , and Tv_3 , and that of the detected raw fuel gas temperatures Tg_{in} , Tg_1 , and Tg_2 Tg_{in} , are calculated and they are compared with the value described in the table for the ΔTv -injection pattern. This can select newly injector or injectors to be injected again. As a result, an adequate amount of the raw fuel gas required can be quickly supplied with good response to the later reactor, reformer 2. Moreover, because of improved control of the temperature of the raw fuel gas FG, the heating portion, which has hitherto be provided at the outlet side of the fuel evaporator, is not required.

[0040]

Next, the control flow of the controller 100 for the raw liquid fuel injection will now be described by referring to Fig. 10, in order to secure the amount of evaporating the raw liquid fuel at the time of accelerating the vehicle.

7. The controller determines an increase in the opening of the throttle ($\Delta \theta_{th}$), and confirms whether or not there is an

increase in the opening of the throttle ($\Delta\theta_{th}$) (S21).

If the increase in the opening degree of the throttle ($\Delta\theta_{th}$) does not exist, the controller enters in the stationary operation routine (S38) to maintain the present operation situation.

8. If the increase in the opening degree of the throttle ($\Delta\theta_{th}$) exists, the controller compares the increase in the opening degree of the throttle ($\Delta\theta_{th}$) with the threshold k of the acceleration degree to judge whether the increase in the opening degree of the throttle ($\Delta\theta_{th}$) is middle acceleration or full acceleration (WOT) (S22).

9. If the increase in the opening degree of the throttle ($\Delta\theta_{th}$) exceeds the threshold k of the acceleration degree, i.e., the vehicle is in middle acceleration or full acceleration (WOT), the controller judges the situation of actuating the injectors 41A (41A₁, 41A₂, and 41A₃), 41B and 41C, i.e., whether or not each of the injectors is turned off (S23).

(A) In order to actuate the injectors 41A, which are stopped, the injection amount of the raw liquid fuel is calculated as an actually required injection time, T_i , from the various correction terms (correction terms such as battery voltage, etc.) (S27). Next, a map 3 for increasing the injection amount of the injector is read (S28). Next, the injector(s) 41A having not been actuated are actuated to inject the raw liquid fuel FL. The raw liquid fuel FL is intermittently injected while pulse-controlling the injection time T_i (S29).

As described above, by injecting the raw liquid fuel from the injectors facing to the thermal transmission surfaces to which no raw liquid fuel FL is injected, the generation of the raw fuel gas as the amount for the acceleration can be effectively compensated with good response.

(B) With regard to the injectors 41A under operating, the amount of the raw fuel gas as the increase is calculated as an actually required injection time (additional time) from the various correction terms (the correction terms such as battery voltage, etc.) (S24). Next, a map 2 for increasing the injection amount of the injector is read (S125). The raw liquid fuel FL is intermittently injected while pulse-controlling the injection time T_i (S26).

(C) If the temperature Tg_2 of the combustion gas at the inlets of the second evaporation chamber 11B and the third evaporation chamber 11C exceeds the threshold temperature Tg_{low} of the combustion gas at the lower side as a result of injecting the raw liquid fuel FL in S26 and S29, the step is returned to S27.

(D) When the temperature Tg_2 of the combustion gas at the inlets of the second evaporation chamber 11B and the third evaporation chamber 11C is lower than the threshold temperature Tg_{low} of the combustion gas at the lower side, the injectors 41B and 41C are turned off (S31), and the injection amounts of the raw liquid fuel from the injectors 41A₁, 41A₂, and 41A₃ are increased (S32).

This makes it possible to secure the amount of generating

the raw fuel gas FG even if the temperature of the combustion gas HG is decreased, and to keep the temperature of the raw fuel gas. Thereafter, the step is returned to S21.

10. In the case where the increase in the open degree of the throttle ($\Delta\theta_{th}$) is lower than the threshold k of the acceleration, i.e., in the case where the requirement for the acceleration is not so strong, the controller judges whether or not the injectors 41A₁, 41A₂, and 41A₃ are operated (S33).

The injectors 41A which are not operated, should maintain the stopping state (S37). Thereafter, the step is returned to S21.

With regard to the injectors 41A under the operation, the injection amount of the raw liquid fuel is calculated as an actually required injection time, T_i , from the various correction terms (correction terms such as battery voltage, etc.). Next, an injector increase map 1 is read (S35). Based upon the calculated values and the injector increase map 1, the raw liquid fuel FL is intermittently injected while pulse controlling the injection time T_i (S36). By such a treatment, the requirement of increasing the raw fuel gas FL for a slight acceleration of the vehicle can be dealt. Then, the step is returned to S21.

As described above, the controller can judge whether the vehicle is under acceleration from the increasing of the open degree of the throttle, and controls the injection amounts and the injection position of the raw liquid fuel FL, certainly

securing the required amount of the raw fuel gas FG at the time of the acceleration even if the temperature of the raw fuel gas FG is not controlled.

The fuel evaporator according to the embodiment can also provide a raw fuel gas having a suitable temperature range.

The fuel evaporator according to the fourth embodiment is not restricted to the above embodiment, and various modifications can be made.

[0041]

For example, while the evaporation chamber in this embodiment is divided into three serially connected evaporation chambers, the number of the divided evaporation chambers may be two or four or more. Also, the combustion gas passages which are passages for the high temperature thermal medium may be provided on the upper surface of the evaporation chamber. By such a configuration, the escape of the heat from the upper surface of the evaporation chamber can be prevented. The catalytic combustor may be replaced by a combustion burner or an electric heater. As the high temperature thermal medium, the combustion gas whose heat is exchanged with air or a liquid, an air or a liquid heated by an electric heater may also be used.

For example, in the case where the heat value of the combustion gas is excess, part of the combustion gas is bypassed at the outlet of the catalytic combustor to be discharged. Conversely, in the case where the heat value of the combustion gas is lacking, auxiliary fuel such as methanol is electrically

heated to be evaporated, and the evaporated auxiliary fuel is combusted in the catalytic combustor to increase the heat value of the combustion gas. The fuel cell is not restricted to a macromolecular type and may be a phosphoric acid type fuel cell (PAFC). Also, this embodiment may be performed irrelevant to the shape of the evaporation chamber. Moreover, various embodiments may be combined.

[0042]

As described above, according to the present invention;
(1) a suitable amount of the raw fuel gas can be supplied to the reactor within an appropriate temperature region depending on various operation modes, environments or such.

(2) at the time of acceleration, since supplement of heat source according to the increasing of the raw fuel gas required is delayed, the generation of raw fuel gas corresponding to the increasing amount due to the acceleration can be compensated with good response by injecting an injector corresponding to the heat transfer surface into which no raw fuel has not yet been injected.

Consequently, depending upon the demand of the acceleration, the raw fuel gas can be supplied with good response.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 shows the configuration of a fuel cell system, in which a fuel evaporator according to the first embodiment of the present invention is used.

Fig. 2 is a partial cutaway plane view of the fuel evaporator according to the fourth embodiment of the present invention.

Fig. 3 is a cross-sectional view taken along the line A-A of Fig. 2.

Fig. 4 is a cross-sectional view taken along the line B-B of Fig. 2.

Fig. 5 is a cross-sectional view taken along the line C-C of Fig. 2.

Fig. 6 is a block diagram showing the control system of the fuel evaporator according to the fourth embodiment of the present invention.

Fig. 7 is a drawing showing the relation between the position of injection of the raw liquid fuel in an evaporation chamber and the temperature of the raw fuel gas at the outlet of the evaporation chamber.

Fig. 8(a) is a drawing explaining an aimed temperature range and a tolerance temperature range of the raw fuel gas, and Fig. 8(b) shows a basic injection pattern at a stationary state.

Fig. 9 is a flowchart showing the control of the fuel evaporator according to the present invention at a stationary state.

Fig. 10 is a flowchart showing the control of the fuel evaporator according to the present invention at an accelerated state.

Fig. 11 shows the relation between the temperature of the raw fuel gas generated during the evaporation of the raw liquid fuel and the operation power.

Fig. 12 is a cross-sectional view showing the conventional fuel evaporator.

[Description of Symbols]

- 1 Fuel Evaporator
- 10 Body of Fuel Evaporator
- 11 Evaporation Chamber
- 11b Bottom Surface
- 12A, 12B, 12C Heat Medium Tube
- P1-P11 Passage
- 20 Catalytic Combustor
- 30 Means for Controlling Injecting Raw Fuel
- 40 Device for Injecting Raw Fuel
- 41A, 41B, 41C Injector
- FG Raw Fuel Gas
- HG Combustion Gas (High Temperature Medium)

[Name of Document] Abstract

[Abstract]

[Problem]

A fuel evaporator, which can secure sufficient response to a sharp change in the load, which can supply a raw fuel gas at an appropriate temperature into the later reformer, and which can satisfy high requirements of the fuel cell system for carrying a fuel cell/electric automobile is provided.

[Means for Solving Problem]

A fuel evaporator composed of an evaporation chamber which evaporates a raw liquid fuel by a high temperature thermal medium to provide a raw fuel gas. The evaporation chamber comprising a plurality of evaporation chambers 11A, 11B, 11C serially connected to each other in a ventilation manner, and at least one raw liquid fuel injector for injecting said raw liquid fuel being provided on each of the plurality of evaporation chambers 11A, 11B, 11C.

[Selected Drawing] Fig. 3